THE A B C CARDIOGRAM OF RIGHT VENTRICULAR HYPERTROPHY

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Although there are now generally recognized criteria for diagnosing right ventricular (R.V.) hypertrophy from a standard 12-lead cardiogram plus one or more right-sided chest leads (V3R, V4R.) (Wilson *et al.*, 1944; Goldberger, 1947; Myers *et al.*, 1948; Sokolow and Lyon, 1949; Myers 1950; Fraser and Turner, 1955; Camerini *et al.*, 1956; Goodwin and Abdin, 1959) the cardiogram in patients with mitral stenosis is often disappointingly normal.

The present work was undertaken to determine the signs of R.V. hypertrophy in the A B C cardiogram (Trethewie, 1953, 1958) and to see whether the diagnosis of the R.V. hypertrophy could be made more accurate thereby.

Material and Methods

A total of 90 cases have been studied—7 with severe pulmonary stenosis, 14 with slight mitral stenosis, and 69 with mitral stenosis sufficient to warrant valvotomy.

All patients were adults. Patients with cardiographic evidence of left ventricular hypertrophy or right bundle-branch block were excluded.

Mean pulmonary artery pressure was recorded either by cardiac catheterization or at operation in all the patients with mitral stenosis, and right ventricular pressure was recorded by cardiac catheterization in those with pulmonary stenosis.

Cardiography. In all patients the standard leads, unipolar limb leads, and six V leads were recorded with in addition V3R and A, B, and C leads. Particular attention was given to the ventricular complex in leads aVR, V3R, V1, V2, and V5, as well as A, B, and C.

The cardiograms were recorded with a Sanborn Viso Cardiette or a Cambridge direct writer, employing conventional standardization of 10 mm.=1 mv. A, B, and C leads were recorded using lead II, the left leg electrode being placed on the xiphisternum and the right arm electrode being respectively at the manubrium (A), left mid-axilla (B), and right chest base (C) (Trethewie, 1958).

Results

The Ventricular Complex in aVR, V3R, V1, V2, and V5

A dominant R wave in leads aVR, V3R, V1, or V2, or a dominant S wave in V5 is indicative of R.V. hypertrophy. In addition the voltage of the ventricular complex may be taken as evidence of R.V. hypertrophy when R exceeds 3 mm. in aVR or V3R, 5 mm. in V1, 7 mm. in V2, or S is greater than 5 mm. in V5.

Of the 69 patients with mitral stenosis and a mean pulmonary artery pressure greater than 20 mm. Hg, there was cardiographic evidence of R.V. hypertrophy in these leads in 45 (64%) only. Table I shows the incidence of signs of R.V. hypertrophy in various combinations of leads V3R, V1, V2, and V5. Lead aVR is not included because in no instance was it the only lead to show

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TABLE I

INCIDENCE OF SIGNS OF R.V. HYPERTROPHY IN V3R, V1, V2, AND V5 IN 69 PATIENTS WITH MEAN PULMONARY ARTERY PRESSURE GREATER THAN 20 MM. HG

Lead	Number	%	Lead	Number	%
V3R	31	44	V3R and V1 and V2	43	61
V1	29	41			
V2	36	51	V3R and V1 and V5	36	51
V5	24	34			
V3R and V1	34	49	V3R and V2 and V5	44	63
V3R and V2	42	60			
V3R and V5	33	47	V1 and V2 and V5	42	60
V1 and V2	40	59			
V1 and V5	31	44	V3R and V1 and V2 and V5	45	64
V2 and V5	38	54			

evidence of R.V. hypertrophy and when it did show this evidence there was always a dominant R in V3R in the same cardiogram.

Of the 14 patients with slight mitral stenosis and mean pulmonary artery pressure of less than 20 mm. Hg, 1 had a dominant R in aVR, and 1 had a dominant R in V1.

The 7 patients with pulmonary stenosis all showed evidence of gross right ventricular hypertrophy in all leads. (R.V. pressures 80 to 225 mm. Hg systolic.)

The Ventricular Complex in A, B, and C

The R/S ratio was plotted against mean pulmonary artery pressure for leads A, B, and C respectively in the 69 cases of significant mitral stenosis and the 14 cases of slight mitral stenosis. Table II shows the range and average R/S ratios for each group.

TABLE II

R/S RATIO IN LEADS A, B, AND C

	A			B			C		
	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.
Mitral stenosis—normal pressure (14)	1/∞	0·44	0·31†	0·03	0·33	0·19	0·04	0·45	0·22
Mitral stenosis—raised pressure (69)	0·13	∞	1·58*	1/∞	∞	0·68*†	0·1	∞	0·91*
Pulmonary stenosis (7)	0·5	12	3·1	0·43	∞	13·4*	0·5	15·5	3·88

* Excluding those with absent S.
† Excluding those with absent R.

It was found that an R/S ratio equal to or greater than 1/2 in A, B, or C demarcates those with a mean pulmonary artery pressure greater than 20 mm. Hg, although a ratio of less than 1/2 does not necessarily indicate a pressure within normal limits.

These results are highly significant (lead A, $\chi^2=46{\cdot}86$, $P<0{\cdot}001$; lead B, $\chi^2=8{\cdot}11$, $0{\cdot}01>P>0{\cdot}001$; lead C, $\chi^2=23{\cdot}21$, $P<0{\cdot}001$).

Table III shows the incidence of this sign in various combinations of these leads. It will be seen that with these criteria there was evidence of R.V. hypertrophy in 64 out of 69 cases (90%). Indeed, lead A alone proved diagnostic in 61 out of 69 (87%) (Fig. 1).

In the 7 cases of pulmonary stenosis the R/S ratio was equal to or greater than 1/2 in one or more of the A, B, C leads in each case.

A typical A, B, C display from each group is shown in Fig. 2.

TABLE III

INCIDENCE OF R/S RATIO OF 1/2 OR GREATER IN A, B, AND C IN 69 CASES OF MITRAL STENOSIS WITH MEAN PULMONARY ARTERY PRESSURE GREATER THAN 20 MM. HG

Lead	Number	Percentage
A	61	87
B	27	39
C	48	69
A and B	62	89
A and C	62	89
B and C	49	70
A and B and C	63	90

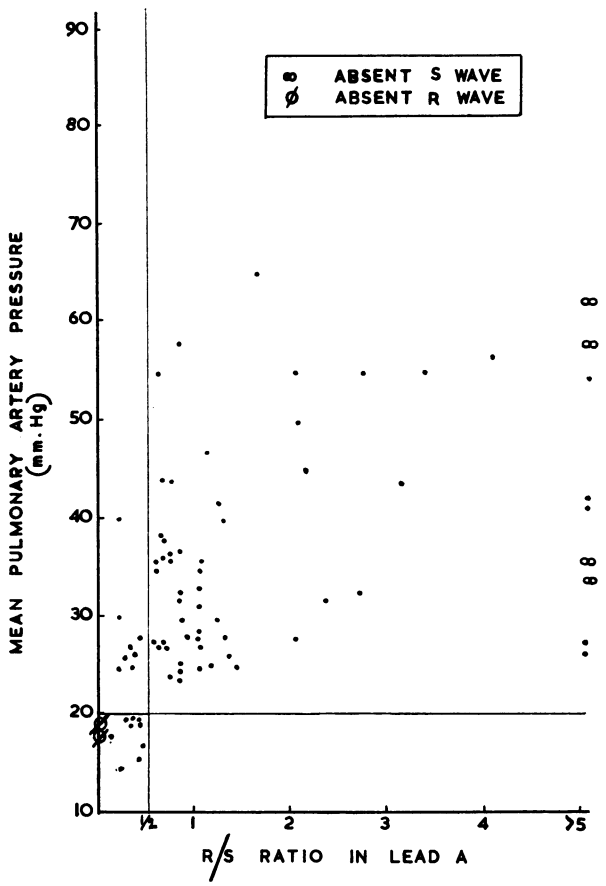

FIG. 1.—R.S. ratio in lead A plotted against mean pulmonary artery pressure in mm. Hg

The R wave voltage was plotted against the mean pulmonary artery pressure for leads A, B, and C respectively in the 83 cases of mitral stenosis. Table IV shows the range and average R wave voltage for each group.

An R wave greater than 0·4 mv. in A, or greater than 0·7 mv. in B, or greater than 0·5 mv. in C was only met in those with mean pulmonary artery pressure over 20 mm. Hg, although the converse

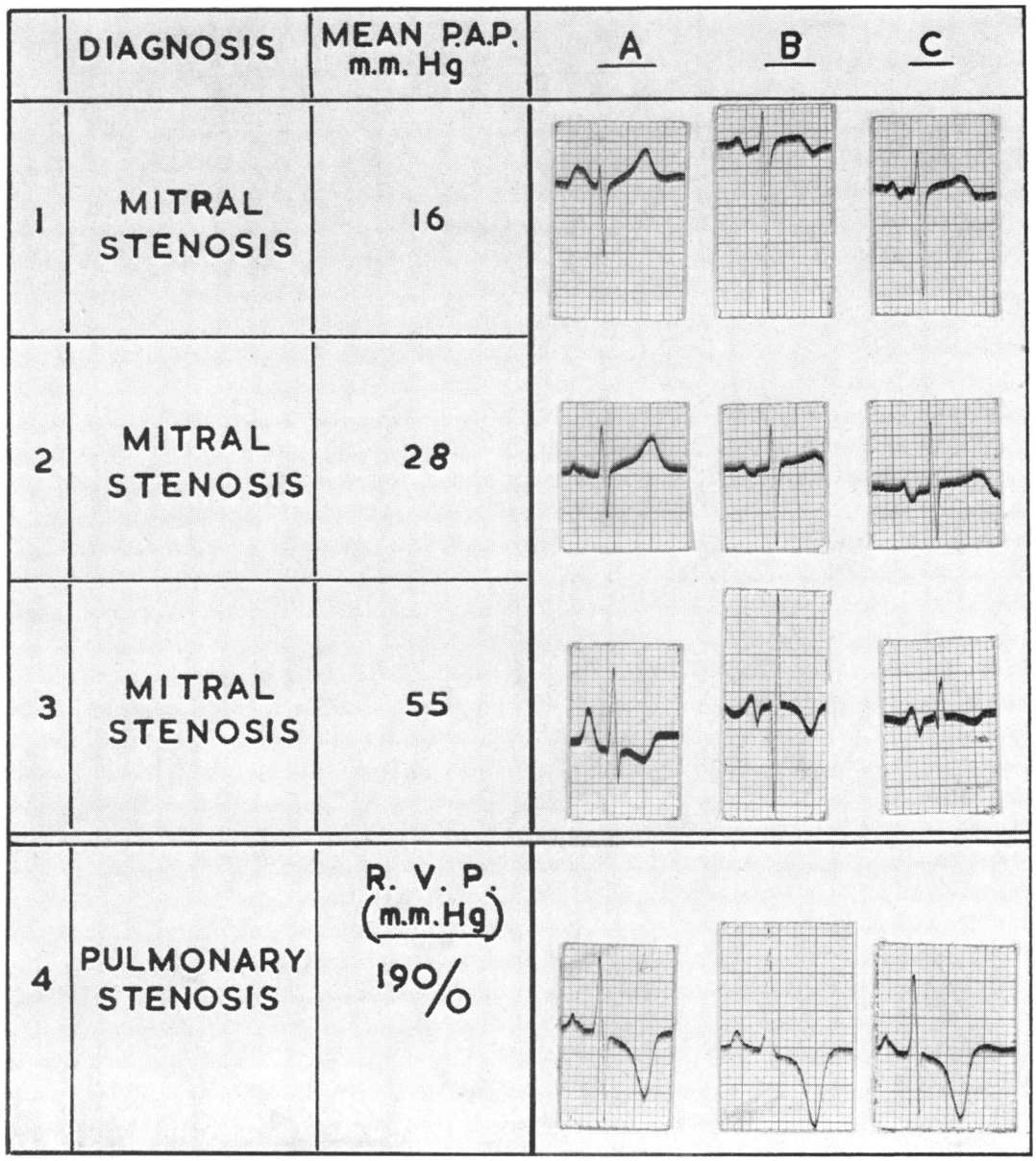

FIG. 2.—A, B, C leads in patients with (1) mitral stenosis and normal pressure, (2) mitral stenosis and mild elevation of pressure, (3) mitral stenosis with considerable elevation of pressure, and (4) pulmonary stenosis. Note similarity of (3) and (4) but much steeper T inversion in pulmonary stenosis.

was not true, smaller voltages being seen in some patients with raised pressures. The 7 cases of pulmonary stenosis, however, all showed very large R waves in all leads (Table IV).

Applying these voltage criteria, R.V. hypertrophy was indicated only in 55 (80%) of the 69 cases of significant mitral stenosis.

Combining criteria of the R/S ratio and the R voltage gave a diagnosis of R.V. hypertrophy in

TABLE IV

R WAVE VOLTAGE IN MV. IN A, B, AND C.

	A			B			C		
	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.
Mitral stenosis—normal pressure (14) ..	0	0·4	0·2	0·1	0·7	0·36	0·1	0·5	0·28
Mitral stenosis—raised pressure (69) ..	0·1	4·0	0·9	0	3·0	0·72	0·2	5·0	0·78
Pulmonary stenosis	0·8	3·5	2·1	0·8	3·5	2·1	1·0	3·2	1·9

64 (93%) of the 69 cases of mitral stenosis with a mean pulmonary artery pressure over 20 mm. Hg. This is not significantly different from the result with R/S ratio alone.

T Wave Inversion in Leads A, B, and C. T wave inversion persisting on deep inspiration in lead B was present in 44 (63%) of 69 cases with significant mitral stenosis, and in the 7 cases of pulmonary stenosis, but was also present in 7 (50%) of the 14 cases with normal mean pulmonary artery pressure.

T wave inversion in leads A or C was present in 19 of the cases of mitral stenosis with raised pressure, all 7 of the pulmonary stenosis cases, but in none of the cases with normal pressure. T wave inversion in general occurred in the cases with the highest pressures: the average value of the mean pulmonary artery pressure in the cases with T inversion in A or C was 48 mm. Hg; in those without T inversion but with raised pressure it was 33 mm. Hg.

It would appear, therefore, that T wave inversion in lead B is of no importance but that T inversion in leads A or C indicates a severer degree of R.V. hypertrophy.

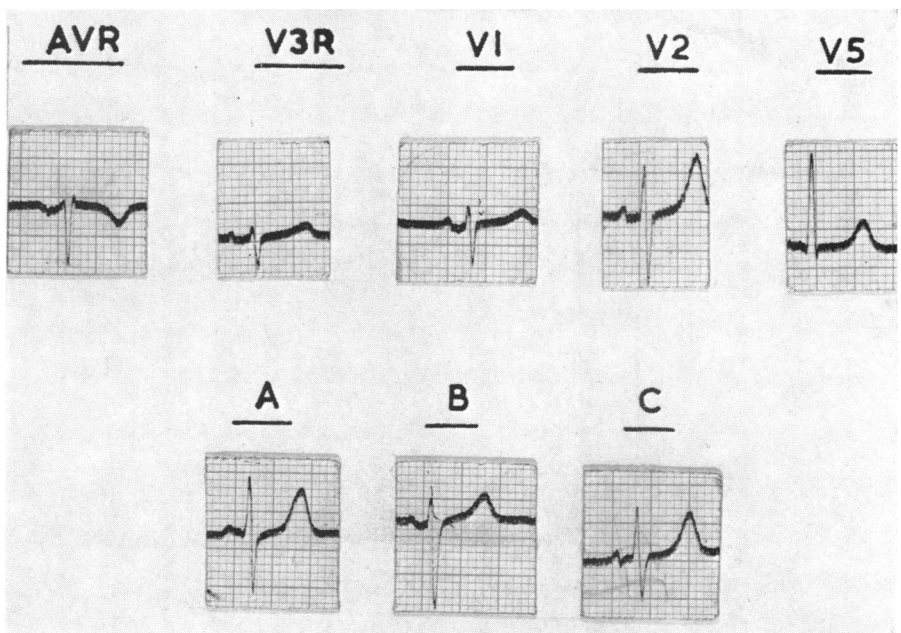

FIG. 3.—Cardiogram from patient with mitral stenosis and mean pulmonary artery pressure of 33 mm. Hg showing no evidence of R.V. hypertrophy in aVR, V3R, V1, V2, or V5, but R/S ratio greater than 1/2 in A and C.

Discussion

The standard unipolar limb and chest leads record electrical activity almost solely in the frontal (coronal) plane. The simple A, B, and C curves, however, permit a three-dimensional analysis. From consideration of these leads it may be predicted that R.V. activity would be maximal in A (xiphisternum-manubrium); left ventricular activity in B (xiphisternum—left mid-axilla); and septal events in C (xiphisternum—right chest base).

The present study shows that it is almost as accurate to use lead A alone in diagnosing R.V. hypertrophy (signs in 87%) as to use A, B, and C (90%) confirming that R.V. events are displayed maximally in this lead. Similarly, as might be expected, B displays R.V. events minimally; while C is intermediate, the results in this lead possibly being due to rotation.

The proportion of cases with raised mean pulmonary artery pressure in this series with cardiographic evidence of R.V. hypertrophy on a standard display of 12 leads plus V3R was only 64 per cent, compared with 90 per cent on the A, B, C display. This is highly significant ($\chi^2=20{\cdot}47$; $P<0{\cdot}001$). It is therefore suggested that the latter are superior for this purpose (Fig. 3).

A considerable proportion of the patients in this study were subjected to cardiac catheterization largely because of the discrepancy between cardiographic and clinical or radiological findings. It is submitted that the use of A B C leads in the future would substantially reduce this number.

At the present time experience with A B C leads is still too limited to justify their replacing the standard display, but it would certainly seem worth adding them to the routine cardiogram: even lead A alone would be an advantageous addition.

Summary

The A B C cardiogram has been analysed in 83 cases of mitral stenosis, 69 with a mean pulmonary artery pressure greater than 20 mm. Hg, and 14 with normal pressure, and in 7 cases of pulmonary stenosis with high R.V. pressure.

An R/S ratio of 1/2 or greater in leads A, B, or C is considered diagnostic of R.V. hypertrophy. It is also suggested that maximal R.V. activity is shown in A; and that T wave inversion in A or C indicates the severer grades of hypertrophy.

In this series the A B C leads showed evidence of R.V. hypertrophy in 90 per cent against only 64 per cent on a 12-lead display plus V3R.

It is concluded that the A, B, C display (or at least lead A) should be added to the routine cardiogram.

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